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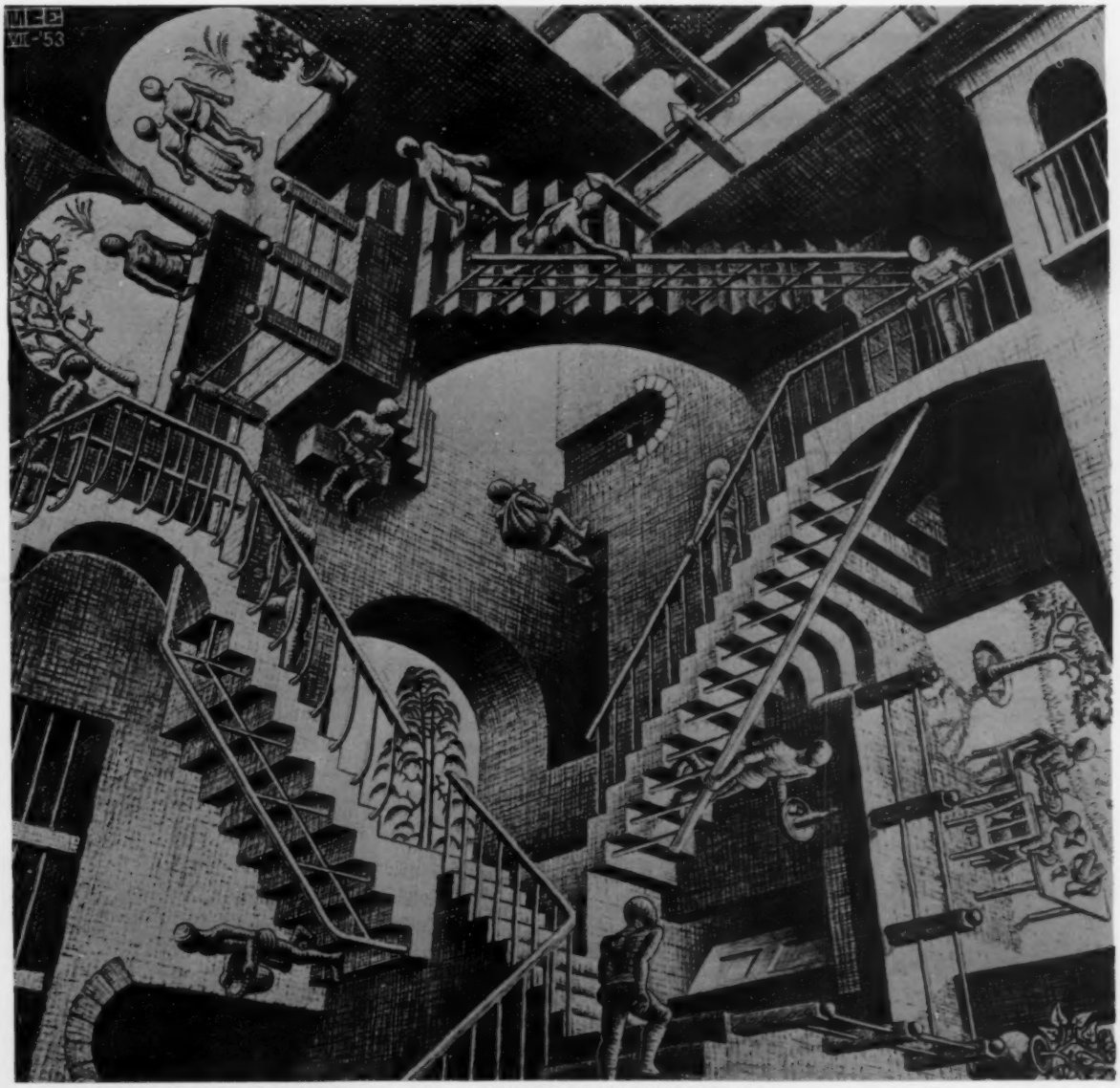

ACHIEVING PERSPECTIVE IN A COMPLEX WORLD **see page 7.**

NATIONAL BUREAU OF STANDARDS

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Cover: This lithograph by M.C. Escher is titled *Relativity.** At first glance, it may appear that the elements in the illustration are randomly—even chaotically—arranged. Quite the opposite, a very formal mathematical order is at work: The people and surroundings "exist" on one of three intersecting planes which cross at right angles, with three forces of gravity working perpendicular to one another. Through this system of orientation, Escher has achieved a study in visual perspective. The underlying order in this complex work of art may be a matter of simple geometry. But the point is that mathematics is a key to "perspective" not only in the world of art, but also in the real world where we daily face the maze of modern living. See page 7.

* Used with permission.
Escher Foundation, Haags Gemeentemuseum, The Hague

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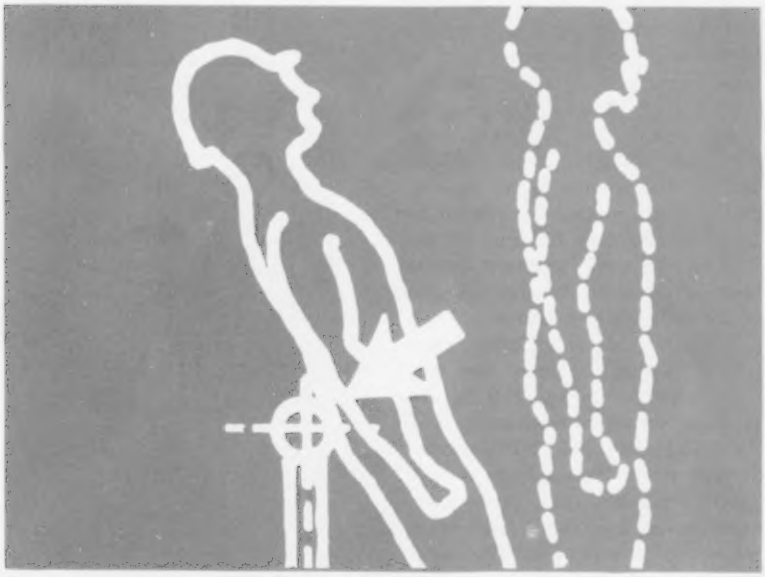
NBS 'FALL GUY' Provides Basis for Guardrail Performance Standard

by Stanley Lichtenstein
NBS public information specialist



CALL him Harry.

A tireless performer in an important experimental role, Harry is a fine figure of a man, with nerves of steel . . . and a head of wood.

Harry—an anthropomorphic dummy—is the "fall guy" in a National Bureau of Standards research project sponsored by the Occupational Safety and Health Administration (OSHA).

Thanks to data generated in experiments involving Harry and a group of human experimental subjects, a proposed model performance standard for personnel guardrails has been developed, with a view to reducing employee casualties.

This proposed standard will be considered by OSHA for adoption. Upon such adoption the provisions of this standard will become mandatory. An analysis of data documented by the New York State Department of Labor indicates that 25 percent of work-surface accidents were guardrail-related, with 35 percent of these involving falls to a different elevation.

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The drawings below depict a number of guardrail experiments, some involving human subjects.

'Fall Guy' *continued*

Harry's Physique

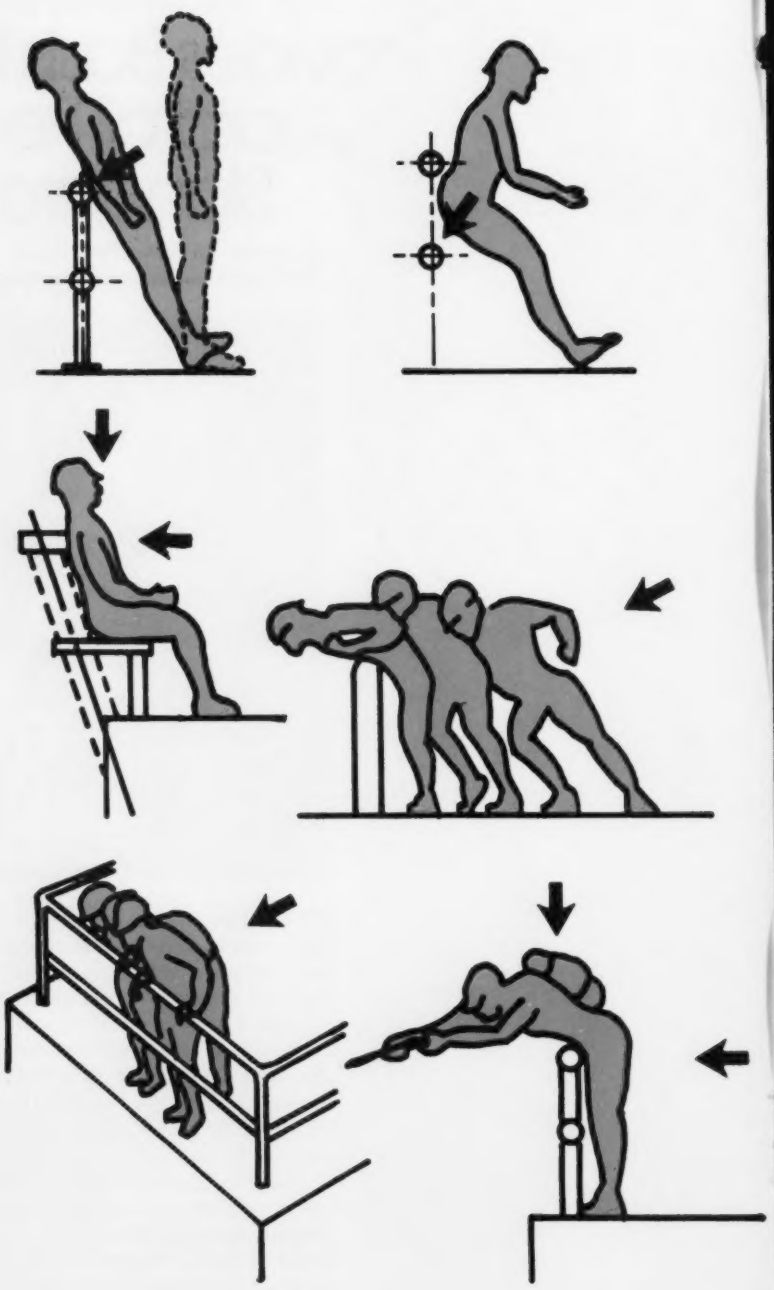
Human subjects have participated in the numerous guardrail tests and measurements conducted by the Structures Section in the NBS Institute for Applied Technology's Center for Building Technology (CBT), but Harry—who knows no fear—is the star of the show. He is right for the part, not only because he is a dummy and "can take it," but also because he has body measurements ideal for the purpose.

Harry's broadly representative measurements and weight distribution, for example, helped in the analysis that went into the development of the proposed criterion for guardrail height of 107 cm. (42 in.). This height would prevent people from falling over the top rail after accidentally walking into it.

Without shoes and clothes, Harry stands 186 cm. (a shade over 6'1") tall and weighs 97 kg. (214 lbs.). For the experiments, he wore safety work shoes and a hard hat. This "personal" protection provided a more realistic tread condition (the shoes were rubber-soled, steel-toed) and better control of Harry's stability when standing erect. Harry didn't wear anything else because his bolted joints had to be readily accessible for careful adjustment with a hand wrench when the effect of friction on joint rotation was critical to test results.

Representative Male

In his own way, Harry personifies the so-called 95th percentile U.S. adult male—giving researchers a basis for a standard applicable to virtually the entire guardrail-user population. When he stumbles—or is propelled—against a guardrail, the effects approximate the heavier loads that



Harry falls backwards against a mock-up of a guardrail instrumented for sensing forces caused by leaning, pushing, and falling. The anthropomorphic dummy used in the NBS tests took many such spills as part of research leading to a proposed model guardrail performance standard.

would be exerted on the guardrail under actual conditions of use or abuse. For a dummy, Harry has a remarkably supple body. His skeletal structure is realistically contrived of metal and plastic, and is covered with flesh of flexible foamed urethane and elastomeric skin. His joints provide limb action consistent with the normal human range of movements.

In addition, for primarily static load tests involving little or no risk, CBT staff members—chosen for their proximity to the 95th and 50th percentile weights and heights documented for the U.S. adult male population—served as human subjects. To measure guardrail loads induced by a single individual, a 95th percentile subject was used; load levels induced by a group of people were measured by using 50th percentile subjects.

Tests

Some of the contrived accidents involved:

- Harry falling graduated distances onto forklift-mounted plywood boards, held at selected heights by the lift, to simulate falls onto wall barriers and railing benches.
- An instrumented mock-up rail assembly, actually a force transducer calibrated so that measured values of longitudinal strain in the rail when deflected were converted to corresponding values of transverse force.
- An intermediate rail test apparatus for simulating a two-rail (top and intermediate) guardrail to investigate the impact on a midrail when struck by a body which first hit the top rail.
- A bending test apparatus for conducting strength tests on common falls.

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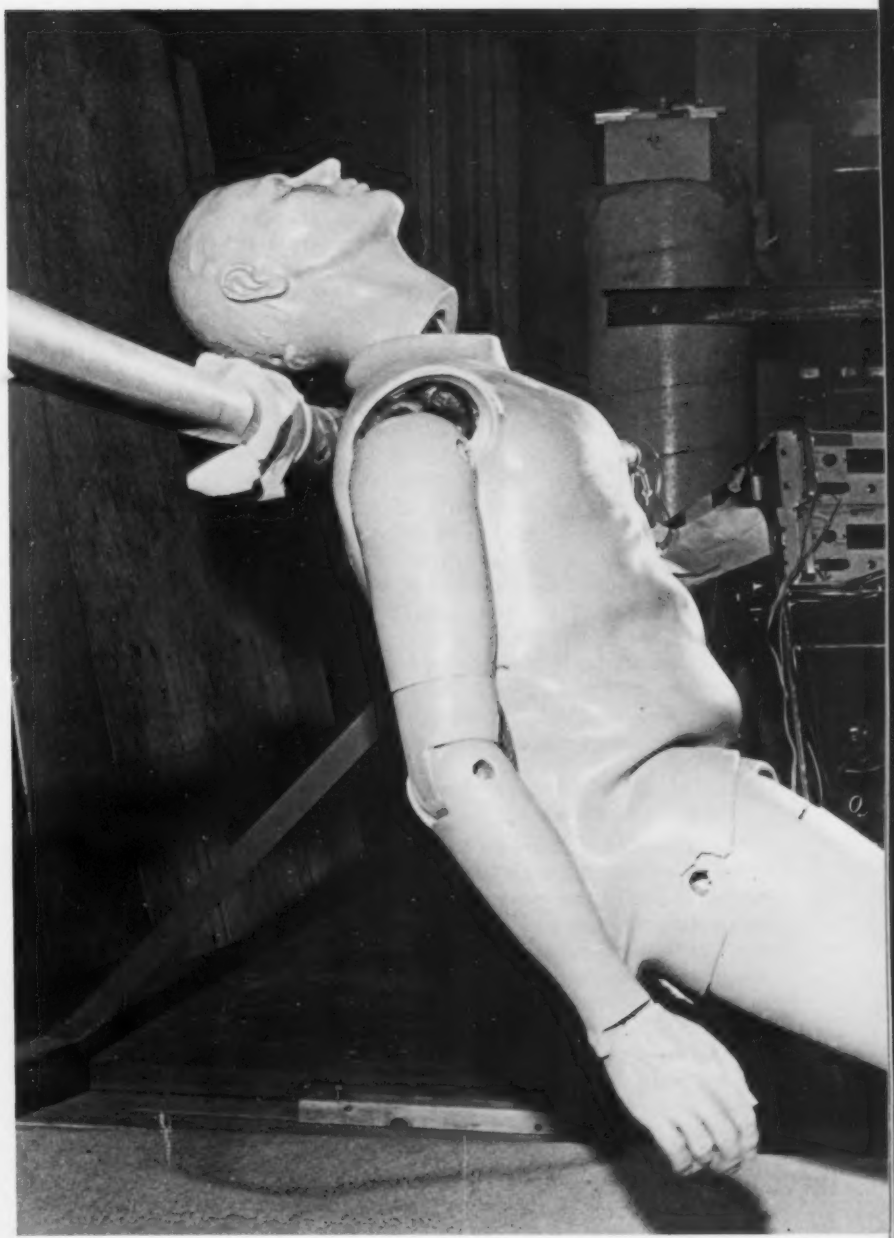


- A tensioned, flexible wire rope rail to demonstrate interaction between transverse loads and deflections.
- Measurements of loads exerted by human subjects sitting on a simulated midrail bench, leaning outward, or conducting other activities that would develop a thrust against the top rail.
- Standing Harry against a vertically adjustable top rail on a special carriage and propelling it against a rigid block anchored to the floor—an experiment designed to determine the necessary guardrail height to prevent accidental falls from heights.

Among other things, the CBT researchers looked into the effectiveness of varying the height of a wall barrier to inhibit a subject trying to assume a climbing posture (with one foot on the rail) in order to gain reach advantage. In another phase of the experiments, they analyzed the interrelationships of the height and width of a barrier and the initial distance of Harry's heels from the near face of the barrier as he fell backwards against it. This was done in order to study the protective function of the wall barrier.

Loadings

"Surge loading," caused by a large group of people pushing against the barrier, is one of the more demanding challenges to guardrail design, and the CBT researchers gave it proper attention. Measurements were made of loads transmitted by people pushing each other against an instrumented mock-up guardrail to simulate disorderly exit conditions of a crowd.

Various other kinds of anticipated live loads were considered by the experimenters. Such loads were divided into two categories: live loads occasioned by routine activities requiring structural support from the guardrail, and live loads resulting from common forms of inadvertent guardrail misuse. The first category includes use of guardrails for the support of workers and equipment in an elevated platform tree-spraying operation. Examples of the second category are a crowd leaning over the rail to watch an interesting event several stories below, people sitting on a bench and leaning against the rail, and people propping their feet or sitting on midrails.

In addition to Harry and the human subjects, a number of rudimentary items were used in the tests. Recommendations for the sizes of openings in guardrail systems are based on the premise that if an opening rejects passage of a spherical object 46 cm. (18 in.) or greater in diameter, the guardrail system would considerably impede accidental passage of employees through its openings. The spherical object's diameter corresponds to the shoulder width of the 50th percentile U.S. male.

Similarly, to prevent the foot, hand tools and small debris from falling or sliding over the bottom edge of guardrails, a proposed criterion specifies that guardrails should reject the passage of spherical objects 1.3 cm. (0.5 in.) in diameter up to a height of 13 cm. (5 in.) or less from the adjacent floor surface. Ankle pivot height of the 95th percentile U.S. male wearing heavy winter shoes was the basis for this recommendation.

Further Provisions

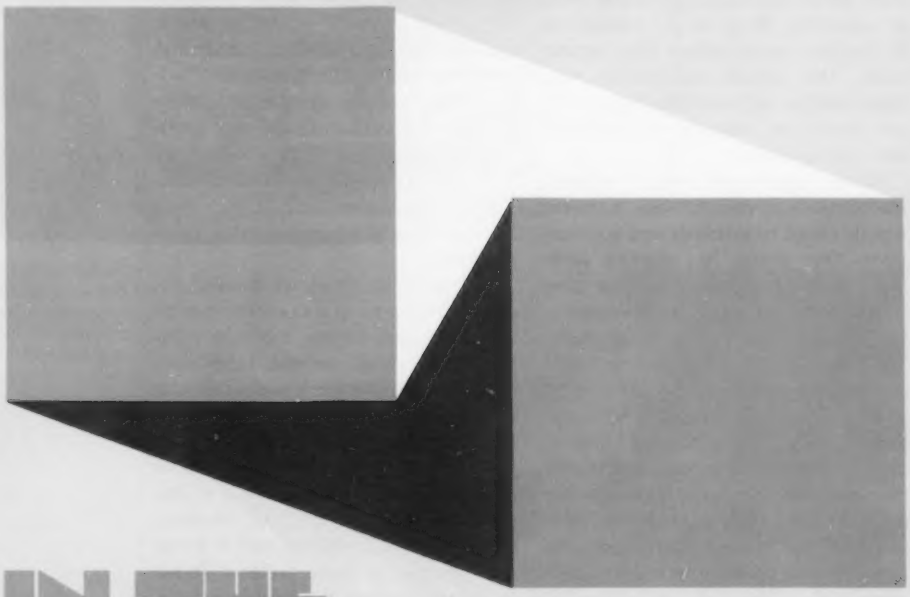
The NBS researchers, under the direction of Dr. S. George Fattal, project leader, used Harry, human subjects, spherical objects and other appropriate items in order to explore broadly the problem before them. The experimenters sought to anticipate a variety of situations and to deal with every aspect of guardrail safety. Thus handrails—ordinarily not intended to serve as work area accident preventers—were included in the experimental design with respect to situations in which they perform guardrail functions, "such as when located along the precipitous edge of a stairway or around elevated landings. . . ."

One of the recommended criteria provides an inspection procedure and field testing of guardrail surfaces and edges that are to be "smooth and void of characteristics that can capture clothing or cause cuts, snags, abrasions, or other injuries. . . ."

Another criterion requires providing color contrast to insure guardrail visibility up to 7.6 m. (25 ft.) away. This viewing distance is related to commonly accepted values of human reaction time as determined in Bureau of Public Roads tests of motorists' reactions and average stopping distances. Similar considerations led to a criterion for the placement and legibility of guardrail warning signs prohibiting people from sitting, standing or leaning on the rail, and so on.

These and other provisions of the NBS-proposed Model Performance Standard are dedicated to the furthering of more effective guardrail systems for the protection of employees against occupational hazards. Results of the experiments in which Harry has starred should mean fewer "fall guys and gals" in workplaces around the Nation. □

The Role of MATHEMATICS



IN THE REAL WORLD

by Michael Baum
staff writer

ALL around us we see examples of one of the chief characteristics of modern life—the growth of complexity. In science, in politics, in government and in our private lives we are becoming more and more aware of how complicated things can get.

This leads to a fairly fundamental problem, which is: How do we deal with systems and situations that have become too tangled to be easily understood? Finding an answer to that question is part of the work of applied mathematicians at the National Bureau of Standards.

Complexity

Complexity is one thing that mathematics is accustomed to, explains Alan Goldman, chief of the Opera-

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tions Research Section, "We're used to expecting things to be connected in insidious ways rather than simple ones. The simple case where you have one or two variables that interact nicely we consider an unusual and special case."

What specifically does applied mathematics cover? At NBS, it covers a wide range of interests and applications. One group has studied sampling methods designed to give state weights and measures officials statistically valid ways of checking packaged goods for compliance with regulations.

To the Federal Aviation Administration, NBS mathematicians contributed a "simulation model" (DELCAP) that analyzes the performance of air traffic control systems, estimates the number of planes that can be handled, and predicts how delays will arise.

In cooperation with the NBS Center for Building Technology, applied mathematicians developed the survey techniques used to gather data on the causes of lead-paint poisoning of children, and later developed the procedures for analysing the data.

On a more theoretical level, Bureau mathematicians are looking for ways to improve the mathematical functions commonly used in computer programs. Many functions written into programs, they find, are only special "real-valued" cases of complex functions. It may be possible to replace many of these "special cases" with a smaller number of more general functions.

Real-World Problems

Most of these examples, no matter how different the individual situations, can be looked at as problems in coping with complexity. Often it is a case of fitting scientific results for simple experimental cases into complex real-world problems. "Science has usually progressed by a ruthless simplification of the problems it deals with," says Goldman. "That's the whole point of a controlled experiment, and it has been an enormously successful intellectual approach."

But what do these controlled experiments mean in a complex world? The lead-paint survey, taken in Pittsburgh, is a good example. Laboratory science can easily analyze the amount of lead in paint chips or dust and dirt, but when children develop high levels of lead in their blood, is it related to the amount of lead in the wall paint? Or doors? Or cabinets? Or in the dust in the room? Or some combination of these factors? Those questions remove the problem from the laboratory and make it a mathematical challenge, an exercise in statistical analysis.

Computers and Applied Mathematics

Computers, with their fantastic computational ability, are one of the mainstays of modern applied mathematics, but by their very complexity they can become part of a dilemma. According to Hans Oser, who heads the Mathematical Analysis Section, "When you have a so-called computer program, before you can pretend to compute a certain function, you are faced with the task of assuring that the program in fact returns the function values correctly and in a finite time."

The problem is more difficult than it seems. Modern computer programs may use thousands of steps to calculate a value for a particularly complicated function and along the way make use of many other functions to reach a solution. To cite a classic example, suppose one of the "subfunctions" is the familiar quadratic equation. If:

$$ax^2 + bx + c = 0 \quad (a \neq o)$$

then the solutions are given by:

$$x = \frac{-b \pm (b^2 - 4ac)^{1/2}}{2a}$$

This formula is mathematically "exact"; in other words, it is valid

Mathematics can be applied to common but unrelated real-world situations, from bus travel to papermaking. A computer program for bus routing can help travellers find the best route to their destination. A computer system for analyzing wood pulp may make recycled paper more economical and useful.

(Photo courtesy WMATA.)

(Photo by Mark Helfer.)

for all values of a, b, and c, as long as a is different from zero. But, when 4ac is much smaller than b^2 (let us say equal to 10^{-6} b^2) our computers with their finite word length suddenly start returning funny answers—lots of incorrect digits and no warning of the impending disaster. A good numerical analyst anticipates these problems and takes care of them in his programs.

The example is simplified, but it is easy to see that any number of nasty traps may be hidden in a particularly complex program. Where the number of variables is large—perhaps whole matrices or collections of variables are used at a single time—it becomes an impossibly difficult task to test the program by brute force, plugging in all possible values and checking for errors. Then the mathematicians have to use what they call "cleverness"—looking, for example, for familiar structures in the program that can be used to analyze the whole.

Timeliness or Accuracy

At the same time, however, the analysts must be careful not to con-

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struct computer programs that, although they give correct answers, may take forever to do it. "Timeliness and accuracy are often mutually exclusive," says Oser, "and in fact there may be good reasons why somebody may want a less than accurate algorithm in return for a faster execution time."

The results of careful analysis of already existing computer programs can be astonishing. In 1969 NBS mathematicians studied several common "packages" for a variety of elementary functions. Oser recalls, "It's now 6 years ago that we took it upon ourselves to test the Fortran library program for the NBS computer. We tested all the elementary functions, and there were errors in nearly every one of them. Some of them were quite severe, leading to such gross errors that not even one figure in the answer was correct."

That computers could be at once one of the strongest tools of modern mathematical analysis and also one of the major problems seems contradictory. However, it is their virtue, the ability to increase by many times the amount of data we can handle and the number of computations we can perform, that leads to the difficulty, according to Russell Kirsch.

Kirsch is head of the NBS Artificial Intelligence Project, a broad term that includes, according to Kirsch, "A field where you're interested in doing things with formal systems—machines, for example. or mathematical algorithms—that seem to require human intelligence, and by being clever about it, doing it without human intelligence."

"Computers," Kirsch says, "are great big intellectual sponges. Using them, a person can build very elaborate objects, such as data sets or programs, by being creative. People are perhaps overly willing and capable of building things on machines."

The problem arises, explains Kirsch, in knowing what has been built. A typical example is a complex computer program, a mathematical algorithm designed to produce some sort of number, perhaps the value of a function under given conditions.

The program itself can be described quite easily. In principle, all the separate commands that go into it could be written down, one at a time, in a series of steps. But it is not enough to describe the program. What is needed is a way to predict its behavior, and this, according to Kirsch, is not always easy.

Turing Machine

The difficulty has been studied with a mathematical abstraction called a Turing machine. A Turing machine has a tape, something that can read what is on the tape, something that can write on the tape, a mechanism for moving the tape either forward or backwards, and a finite set of commands. It is an idealized computer. Turing machines, and thus computers in general, are bound by a theorem of logic proposed in 1931 by Kurt Godel. Godel showed that there is an infinite number of questions about themselves that such machines cannot answer, by their very nature.

Questions such as, "Will this program eventually produce the value 37?" may be theoretically undecidable. We cannot, even with the aid of computers, answer "yes" or "no." But these are precisely the questions about the behavior of the program that we want to ask. "You can ask any number of questions about an algorithm's construction," says Kirsch, "but precious few about its behavior."

"In much of the work of analysis of algorithms, or construction of models, it's comparatively easy to build something that will work, and comparatively difficult to analyze why it's working."

Since it is in theory impossible to analyze much of the behavior of these constructions, the work of applied mathematics in this area is to do the best that may be done with specific cases, knowing that the general case is impossible. The mathematicians use methods of analysis that are known to work for a large variety of cases and exploit the unique nature of special cases.

Broad Applications

Applied mathematics is a field valuable to both the scientist in his lab and the consumer in his home. The applications are obviously very broad. Some of those applications, planned for discussion in DIMENSIONS/NBS, include:

- General computer programs that bus companies can use to provide travellers with the best possible route using one or more buses between any two points in the city, programs that work many times faster than present short-route programs.
- A method of determining whether or not two given graphs or networks are the same—a problem that is more difficult than it appears and quite valuable to chemical analysis.
- A system that will allow computer analysis of wood pulp used for making paper, a key element in making recycled paper more economical. □

A NEW LEASE ON AN ACTIVE LIFE THROUGH SURGICAL IMPLANTS

Scientists join surgeons and manufacturers in search for safer, more durable synthetic implant materials.

by Madeleine Jacobs
NBS public information specialist

THOUSANDS of people are leading active lives today thanks to the progress made by the medical and scientific professions in simulating and replacing defective body parts with man-made devices. In the United States alone, more than 1 million individual orthopedic implants are surgically inserted each year, ranging from metal nails and screws to plates, pins, and prostheses. At least 45,000 artificial heart valves and 100,000 artificial arteries have been implanted since they were first developed.

Despite these successes, the reliability and durability of many synthetic materials implanted in the human body are matters of increasing concern. One reason is the trend toward implantation in younger and more active patients. Until recently, implants generally were inserted only in elderly patients where they were expected to perform their function for 10 to 20 years at most. Today, however, an artificial hip joint implanted in a 30-year old man must be able to perform satisfactorily for 30, or even 40, years. Yet very little is known about the long-term performance of such implant materials and devices. And researchers agree that totally satisfactory and compatible synthetic materials for surgical implants do not now exist.

Another reason for the growing interest in synthetic materials is the Medical Devices Amendments of 1976. This new legislation requires manufacturers to meet strict standards for medical implants or submit them to stringent pre-market clearance before the Food and Drug Ad-

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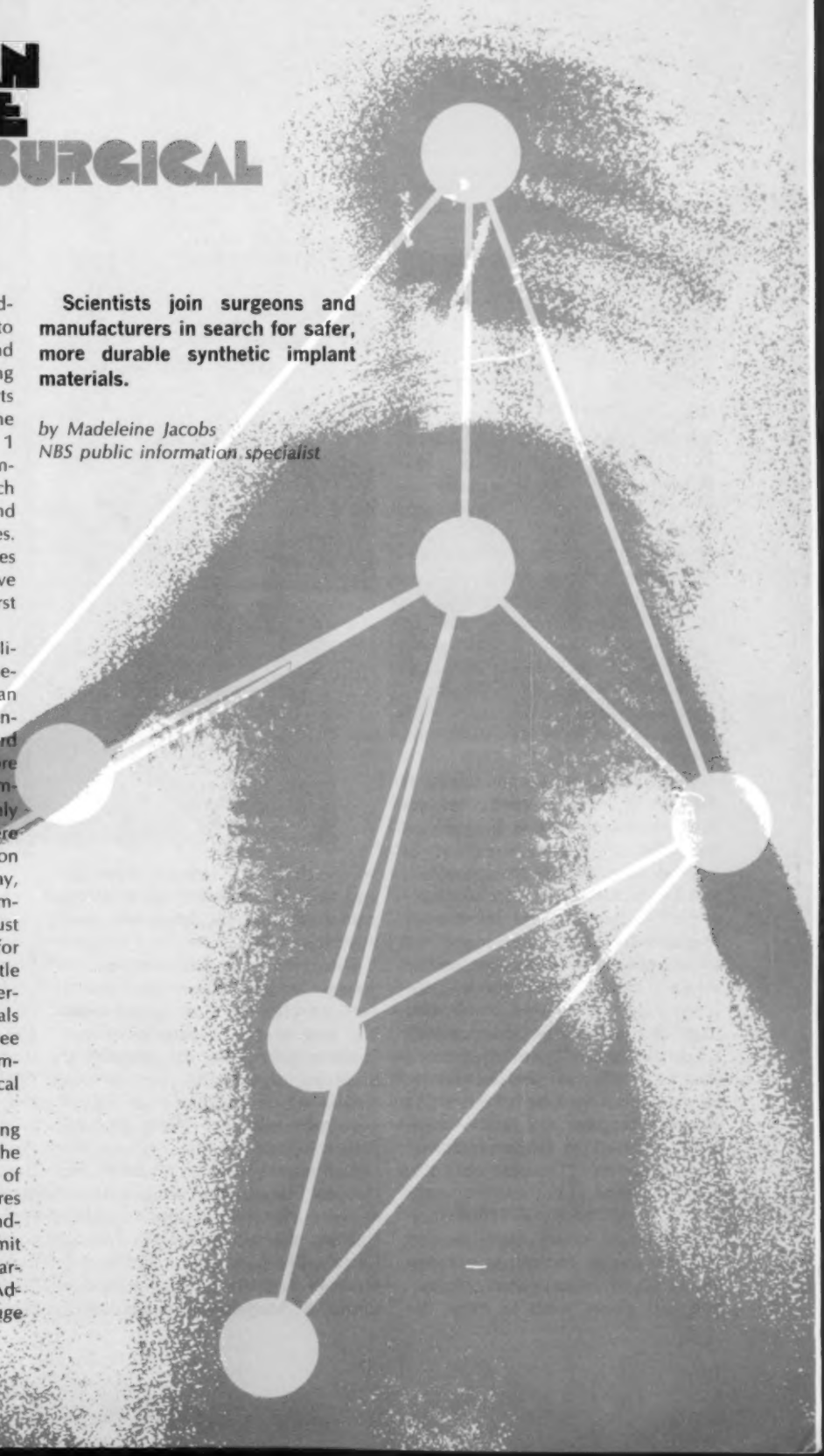


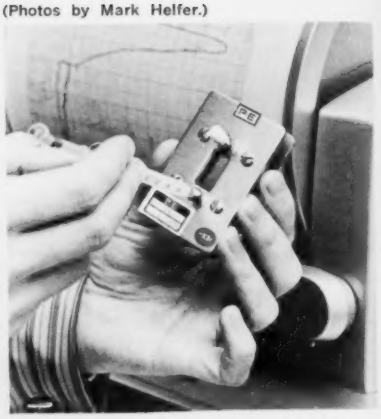
ministration will permit their sale and use. Unfortunately, standards for many implants either do not exist or are inadequate in view of the new legislation.

Standards Needed

These concerns over synthetic implant materials are shared by manufacturers of the materials and devices, government research and regulatory agencies, standards organizations, surgeons, and, of course, prospective patients. Their views are brought together in the American Society for Testing and Materials on Committee F-4, the Committee on Medical and Surgical Materials and Devices. With more than 345 members spread over eight subcommittees, F-4 considers and promulgates voluntary standards.

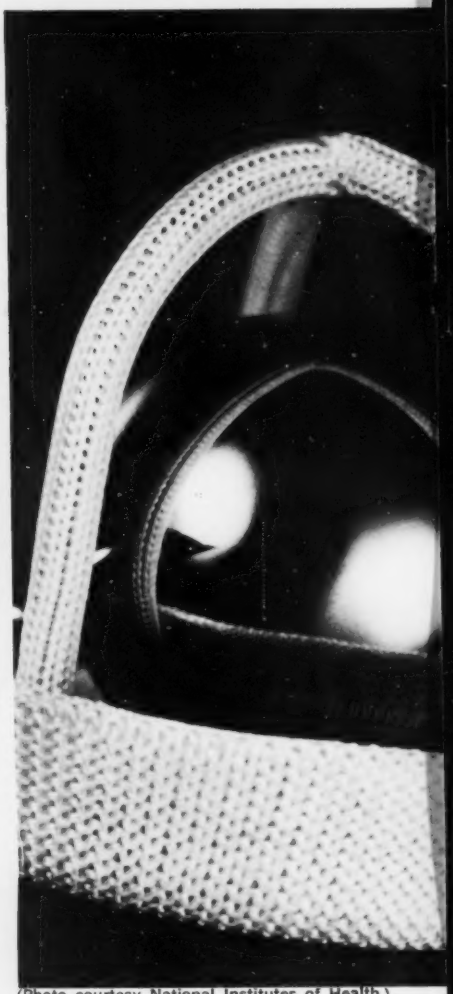
The National Bureau of Standards through its new Synthetic Implant Program is working with these groups to assist in the development of needed standards, specifications, and test methods for materials surgically implanted in the body. IMR Deputy Director Dr. Emanuel Horowitz explains, "Our goal is to develop the broad measurement methods, characterization procedures, and data base on which the optimal materials for implants can be selected for a specific application in the body." Horowitz was instrumental in starting the NBS program and is also chairman of the ASTM subcommittee on such materials. "Through our program, we hope to put into the hands of manufacturers the information they need to select materials and maintain quality control, to put into the hands of surgeons the information that allows them to make the wisest choice of implant materials, and to give added assurance to the patient that he is getting the best material available."

(Photos by Mark Helfer.)



Clots on surface of heart valve (right) are especially dangerous. NBS scientists are studying protein adsorption on implant surfaces since this event is related to initiation of clotting process. Sample (above) is loaded for infrared spectroscopy studies to investigate changes in shape or conformation of proteins adsorbed onto synthetic surfaces.

The NBS program focuses on polymer and metallic implant materials used in the two largest fields of surgery—the orthopedic and cardiovascular areas. The needs and problems of ceramic implant materials—which are now widely used in Europe—also are being studied. Partial support for the work in the cardiovascular area comes from the National Heart and Lung Institute of the National Institutes of Health. Heading the program is Dr. James Cassel, Chief of the Dental and Medical Materials Section in the Institute for Materials Research (IMR).



(Photo courtesy National Institutes of Health.)

Metal Mimics

In the orthopedic field, the most frequently used implants are made of metallic materials—usually stainless steel, cobalt-chromium alloys, and titanium alloys. Metal plates are used to bridge fractures in bones until they have healed and are then frequently removed. Other implants, such as metal nails and pins, are used to strengthen long bones to compensate for severe fractures or degenerative bone diseases. Carefully engineered artificial joints—using a combination of metal and polymer parts and in some cases polymer "cement"—can be used in a variety of locations. The most frequent re-

Chemist Freddy Khoury uses electron microscope to study fine structure of ultra high molecular weight polyethylene used in plastic cups in hip implants.

NBS metallurgist Anna Fraker points out several kinds of metal implants used in surgery, ranging from heart pacemakers to pins and nails

Chemist John Ambrose is working on a lab method that simulates crevice corrosion conditions in the body. He hopes to develop tests useful in predicting how materials will actually perform in the body.

placement is the hip joint—with an estimated 40,000 operations performed each year.

Many problems with metallic implant materials are related to the composition and history of the metal, how it performs in service, in what ways it fails, and how it can be protected against failure. One of the most basic problems is described by Robert T. Rylee, president of the Orthopedic Surgical Manufacturers Association.

"Although we know the general physical characteristics of the metals such as tensile strength, what we would like to know is how these materials actually perform in the body," he says. "To do this, we need to develop a sufficient data base so we can match up laboratory tests on materials with actual performance. This would enable materials to be selected for implants on a more rational basis than is currently done."

Contributing to this data base is one of the goals of research in the NBS Metallurgy Division, where the scientists involved have to learn something about medicine before they can properly carry out their work. Explains Dr. A. William Ruff, chief of the Microstructures Characterization Section, "When a metal implant is inserted in bone or tissue, the normal defense mechanisms of the body try to isolate it from the rest of the body. Tissue grows around the implant in this process." However, body fluids, containing chemicals usually present in the body (including oxygen), seep into contact with the implant and cause corrosion, he explains. This can eventually contribute to fracture or failure. Other problems related to surfaces, composition, or processing of metal implants are fatigue (the tendency of a material to break under cyclic or repeated stress such as would be encountered in a hip implant) and wear (the process by which a material is lost when two surfaces rub together). Both processes can cause an implant to fail or the body to reject the implant.

Beneath The Surface

"Unlike a polymer, the configuration of a metal surface may vary with its environment," Ruff points out.

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"The oxide film initially formed on a metal can change or alter with time depending on its environment. It's essential to determine the nature of the surface films, since the interaction of the implant with the body environment occurs across this interface." For example, Ruff notes that titanium has five different oxide films. "Some of these films are known to be more resistant to corrosion than others. What we don't know are the factors that influence these film changes in the body environment."

Ruff and NBS metallurgist Dr. Anna Fraker have been studying these factors, in particular, the changes in microstructure—the physical appearance or "grain"—of metals and their surface films under various conditions, some simulating conditions in the body. One of their main techniques is transmission electron microscopy, which permits them to see the interior of the metal samples at a magnification of 40,000 or higher. At these magnifications, they can see details of the metal not visible in any other way. Using this tool and corrosion tests, they found that titanium is more resistant to crevice-like corrosion when it is alloyed with small amounts of nickel and/or molybdenum and after it is given a proper heat treatment. (Crevice-like corrosion occurs where solution access to a surface is limited, as in some kinds of implants).

Meanwhile, Dr. Jerome Kruger, chief of the Corrosion and Electrodeposition Section, and Dr. John R. Ambrose are working on a laboratory method that simulates crevice corrosion conditions in the body. Ultimately, they hope the test can be used to predict how materials will actually perform in the body.

In another study, Fraker has been investigating how surface treatments used on metals prior to implantation affect their properties. Electrochemical measurements yield information on the build-up and breakdown of the metal surface oxide films, and transmission electron microscopy allows her to see surface roughness and identify details of the attached surface films. As a result of these studies, Fraker found that washing titanium alloys in alkaline or acid solutions—the procedure currently recommended by ASTM for metals—produces a rough surface. In contrast, the surface remains smooth after it is treated with boiling water or boiling salt water. Fraker expects the information will be used by ASTM in revisions to its recommended practice.

Fraker and a George Washington University guest worker, Ashraf Imam, are also trying to relate microstructure to fatigue properties of metals. "So far, this work has shown that the fatigue life and strength of at least one alloy can be increased many times by proper heat treatment," she says. "Our goal is to learn how changes in microstructures can increase fatigue life in a physiological environment."

Wearing Away

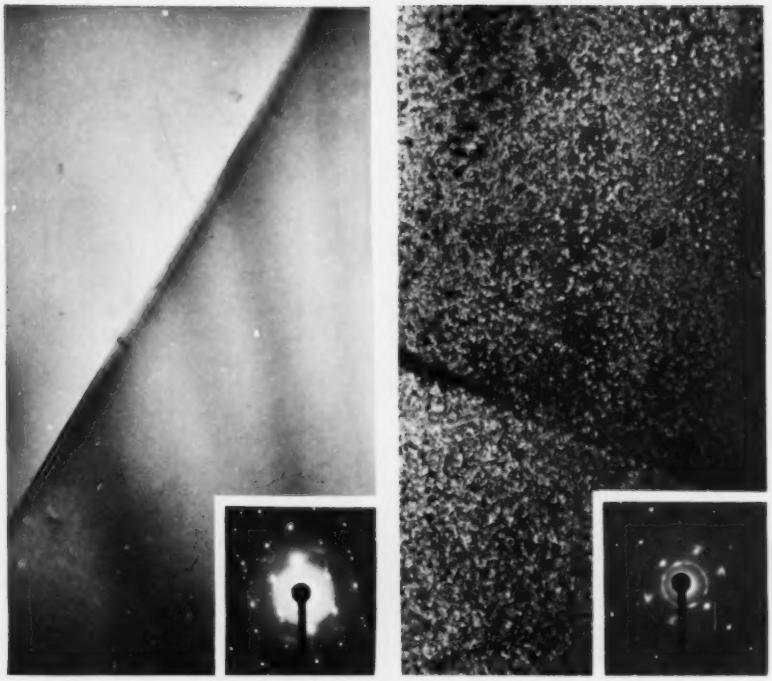
In addition to fatigue, wear is a very worrisome problem in certain implants. "For instance, we know metal implants wear, but what happens to the wear particles, the debris? How do you conduct a useful and meaningful wear test that simulates conditions in the body?" Ruff asks. Currently, he and coworkers are testing alloys of titanium and two cobalt-based alloys rubbing against polyethylene materials — conditions that might be found in a hip implant—under varying loads in different environments. Electron microscopy and x-ray diffraction are used to determine surface damage and the nature of resulting wear debris.

Another aspect related to wear is the subject of research in the Polymers Division where the characteristics of the ultra high molecular weight polyethylene used in implants are being investigated. One of the major uses of this polymer is in the synthetic joint socket, or the plastic "acetabular cup," in artificial hip implants.

"This cup must withstand forces of four to five times body weight, retain its shape for many years under cyclic loading, and exhibit minimum wear," explains NBS chemist Dr. Freddy A. Khoury, who is studying the problem. "We are trying to learn what properties of the polyethylene correlate closely with these requirements." Using optical and electron microscopy and x-ray diffraction, Khoury has examined the fine structure of several compression-molded samples made from ultra high molecular weight polyethylene. These samples, he finds, exhibit a fine grain-like texture which apparently correlates, in terms of dimensions, with the grain-like character of the particles of the raw polymer powder used in the molding operation. The significance of the grain-like texture of the acetabular cups in terms of its relationship to wear performance remains to be determined.

In addition, since the desirable properties of the polyethylene implants are obtainable only when the molecular weight of the polymer is

With transmission electron microscopy (TEM), NBS scientists study surface roughness and identify details of attached surface films on metal to see how treatments used on them prior to implantation affect their properties. On the left, TEM shows titanium metal surface remains smooth after immersion in boiling salt water. Diffuse rings of inserted diffraction pattern indicate a thin layer of TiO (titanium oxide) on the smooth surface. On the right, TEM shows titanium after treatment with hot acid solution. Electron diffraction pattern indicates an oxide film of TiO_2 (anatase) on roughened surface.



very high—on the order of 1 or 2 million—a method for monitoring molecular weight is needed. One such method for determining molecular weight of polymers is measuring the viscosity of dilute solutions. The problem of applying this frequently used technique to this unusually high molecular weight polymer is being investigated by Dr. Herman Wagner.

Bone Cement

The plastic cup in artificial hip joints is attached to the pelvis with a special kind of polymeric bone cement. This same cement is used to fasten the metal stem of the hip implant into the bone. The cement forms a mechanical attachment to the bone and prostheses and serves to steady and cushion artificial parts. Until recently, however, very little was known about the factors that influence the setting and properties of the cement, which is made up of a liquid monomer and a powdered polymer, polymethylmethacrylate (PMMA). NBS chemist Dr. Gerhard Brauer and physicist George Dickson, working with orthopedic surgeon Dr. Stephen Haas of the George Washington University Medical Center, investigated these factors in laboratory tests simulating hip joint replacement operations. (See June 1975 DIMENSIONS.) Brauer and Dickson have also looked at the amounts of monomer and other low molecular weight residuals that remain in the cement after hardening.

As a result of these studies and information from other organizations, ASTM issued its first standard on polymeric implants. The NBS work which contributed to the standard was intended to provide test methods and materials property data so that better quality control procedures could be exercised for this currently widely used material. However, NBS scientists and others have recognized that there may be alternative or improved materials or techniques for attaching the plastic cup and the metal implant to body components.

It's In The Blood

"Cardiovascular implants pose different problems than do orthopedic implants," explains Dr. Leslie Smith, chief of the Polymer Stability and Reactivity Section. "In cardiovascular implants, such as valves and arteries, the major concern is the compatibility of the implant with blood. All materials used to date have tended to damage red blood cells and other elements of the blood, promote clotting, or denature blood and plasma proteins."

The ideal material must produce none of these harmful effects, Smith says. Further, it must meet an imposing array of additional specifications. Not least, it must be tough and durable enough to retain its basic physical characteristics through many years of hard wear in contact with blood. "This is an enormous order," Smith admits. So far the approach has been largely empirical. A material is made and tried. Sometimes it works, sometimes it doesn't. "We're trying to develop chemical and physical data that will shed light on material properties at interfaces that affect blood compatibility. The ultimate goal is to develop tests that predict

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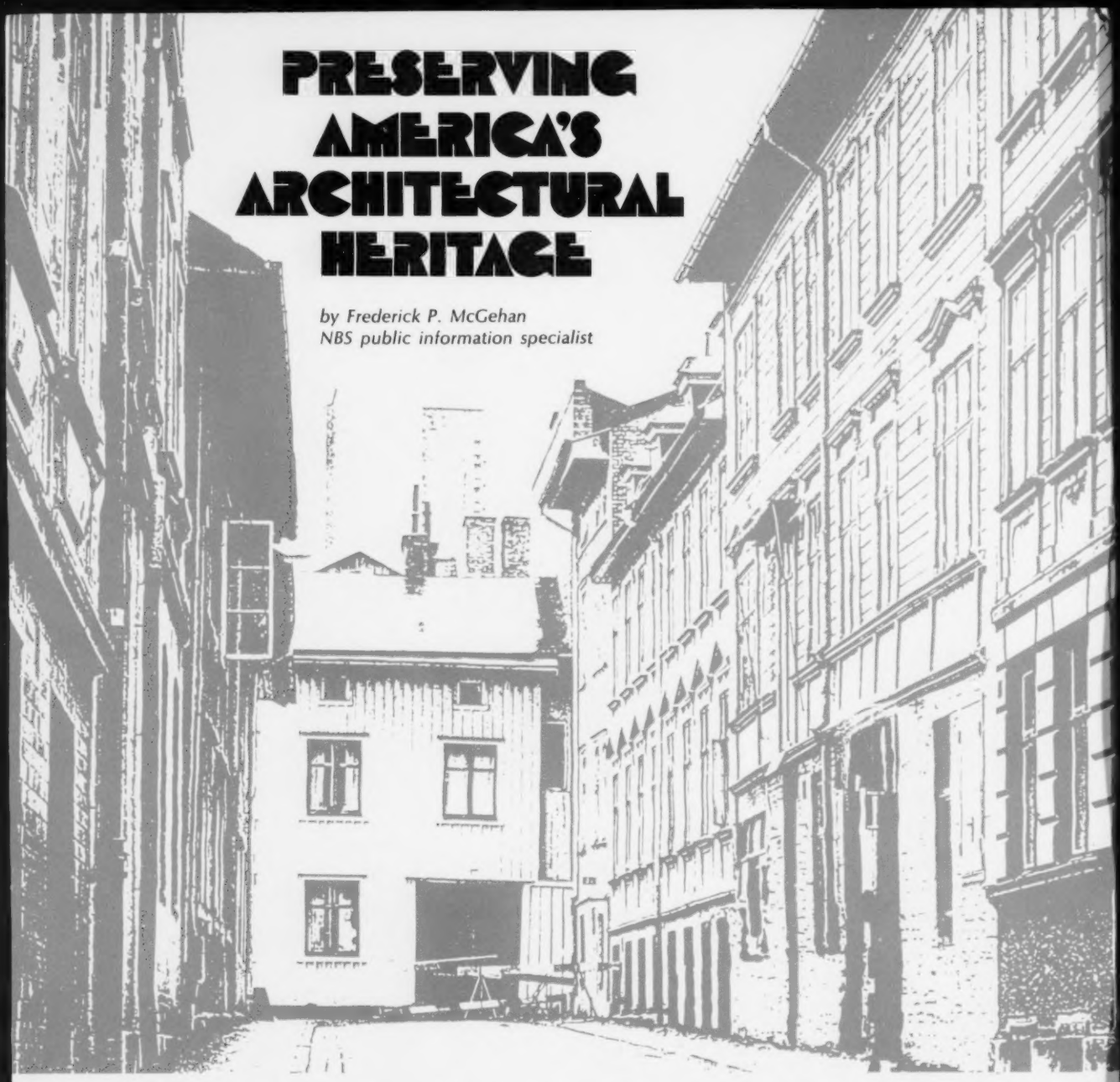
PRESERVING AMERICA'S ARCHITECTURAL HERITAGE

by Frederick P. McGehan
NBS public information specialist



THERE'S a movement afoot in Bicentennial America to restore, renovate, rehabilitate, and preserve old buildings—and, beyond that, to revitalize whole sections or districts of cities that have fallen into disrepair.

The preservation movement, as it has been called, can be traced back as far as the 1850's when the Mount Vernon Ladies' Association was formed to preserve George Washington's Virginia estate. There were a few other examples of this preservation spirit in the late 1800's and early 1900's. But they were usually confined to single buildings of national historic interest.

The present movement had its origins in the 1930's when Charleston, S.C., established the first "historic district" regulations. The effort extended to entire areas of the city and was an attempt to preserve the architectural heritage of an earlier age. It was followed by the reconstruction and restoration of Williamsburg, Va. The attempt was successful in recreating the colonial environment of 18th Century Williamsburg.

In 1966 the Congress passed the National Historic Preservation Act which enlarged the scope of national

preservation policy and established an Advisory Council on Historic Preservation. The act provides grants for restoration of historic properties.

Economic and Social Factors

In more recent years, various economic and social factors have made older areas of large cities desirable locations for restoration. In Washington, D.C., for example, 19th century rowhouses on Capitol Hill and in Georgetown and nearby Alexandria, Va., have become fashionable living areas. In Baltimore, the city has pioneered a movement back to the inner city by the concept of urban homesteading. For just one dollar, a Baltimorean can purchase a structurally-sound rowhouse, on the promise that it will be restored.

One measure of the trend is the phenomenal growth of organizations dedicated to preservation and historical purposes. In 1966 there were 2,500 such organizations at the local level; by 1975 there were more than 6,000.

As the restoration-preservation movement has expanded, it has naturally encountered some obstacles. One of these has been building codes and standards. Designed and refined to meet the needs of modern building construction methods, code requirements are often at variance with structures built long before there were uniform building regulations. The question faced by many local jurisdictions is whether to apply these requirements retroactively or to grant exemptions. And, in granting exemptions, where is the line to be drawn between bending rules to promote restoration and insuring the health and safety of occupants and visitors to those buildings?

NBS Office

The National Bureau of Standards' Office of Building Standards and Codes Services, located in the Center for Building Technology, Institute for Applied Technology, has been one of several government and private agencies that have been examining these questions recently. The first step has been to develop a profile of existing patterns to determine how many states and cities have established provisions for historic preservation and rehabilitation and what these provisions contain.

Patrick W. Cooke of NBS recently directed a survey project that found 16 of 47 responding states and 15 of 24 responding cities have adopted provisions for historic preservation. The survey was conducted by Melvyn Green and Associates, Inc., of El Segundo, Calif., under contract to the NBS Office of Building Standards and Codes Services.

Eleven states reported that they have special code provisions in effect to cover historic structures and five states reported that they utilize special administrative regulations. Nine of the 16 states said they have special boards to regulate preservation. Eight cities reported special code provisions in effect and seven cities reported special administrative regulations.

In Alaska, for example, effort is made to provide for minimum maintenance of historic buildings. There are provisions for historic districts and exemptions are possible for fire and seismic safety considerations. There is a special preservation appeals board where a building official's decisions may be challenged, although Alaska has both building code provisions and administrative regulations dealing with historic preservation.

In Indiana, the state building official may grant exemptions from building code provisions in cases of historic preservation. When such exemptions are granted, the official may limit the number of occupants allowed in the building at any one time, and may require that signs be posted to warn the public that exemptions from state construction and fire code requirements have been granted.

In Oregon, a state Historical Building Review Committee has authority to waive any provision of the State Building Code. The committee consists of the director of the state's Department of Commerce, the state fire marshal, a building official or other local government representative, and the state historic preservation officer. The committee may restrict occupancy in buildings where it grants exemptions.

St. Louis, Mo., has set up historic districts in accordance with special building code provisions and administrative regulations. These districts are administered by the local building official and by the Landmarks and Urban Design Commission. Minimum maintenance standards are provided for designated historic structures.

Enthusiastic Response

There was enthusiastic response to the survey from many of the states and cities, indicating the high degree of interest in this issue. Many respondents mentioned the conflict between rigid code enforcement and the desire to preserve historic structures.

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"This is a matter of critical concern to us," wrote the Wisconsin State Historical Society, "since we are constantly having to petition for waiver of code requirements, particularly as to the number of exits in the buildings.

"Because of this, we are just beginning to look into the possibility of legislation to exempt historic structures from the building code requirements. . . ."

The Utah State Historical Society wrote: "We have a critical need for the type of special historic code provisions you are inquiring about. Our preservation efforts are constantly being frustrated by rigid interpretation of modern codes which cannot be economically or aesthetically applied to historic sites."

The New Mexico State Planning Office said that state is discussing special building code provisions for historic structures. "Too often, the integrity and character of valuable historic structures could be irreparably harmed by the rigid imposition of current safety and health standards as set by our ever-changing building codes," the state office noted.

(National Trust for Historical Preservation photo by Tony P. Wrenn.)

Shown here are restored row houses in the 600 block of A Street, SE., Washington, D.C. Through renovation, the Capitol Hill area is again becoming a fashionable place to live.

More Research Needed

The Green-Cooke study has just begun to scratch the surface of the problem. Additional research is needed to determine how well the various code provisions and administrative regulations are working. It is generally agreed that some code provisions can be abrogated as long as this does not endanger public health or safety. But when these provisions are put aside, what then becomes the designer's liability?

NBS' Center for Building Technology is working on these questions with the National Trust for Historic Preservation and other interested organizations, such as the National Endowment for the Arts, the Department of Housing and Urban Development, and the American Institute of Architects. Representatives of these and other organizations are currently conducting a series of meetings to determine how to prepare building regulations that will meet the needs of preservation and rehabilitation and at the same time provide an acceptable degree of safety.

For the Center for Building Technology, it is an integral part of its mission to improve the building regulatory system—the codes and the more than 1800 different standards referenced in building codes. Hopefully, as a result of the combined efforts of all interested parties, the code enforcement authorities and the historic preservationists will develop ways and means that will allow both parties to do their jobs effectively. □

HIGHLIGHTS

Producing Silicon Semiconductors for Solar Energy Cells

Research is now underway to develop an irradiated form of silicon for use in power devices and solar cells and to expand and extend its application into the semiconductor field. The material, neutron transmutation doped silicon, is being produced from normally available silicon by neutron irradiation in the NBS reactor. The NBS reactor is ideally suited for the transmutation doping of materials due to its extensive and versatile irradiation facilities and its intense, highly thermalized neutron flux.

The element silicon normally contains 3 percent of the ^{30}Si isotope, which transmutes to ^{31}P on the capture of a thermal neutron. This process produces a uniform concentration of phosphorus throughout the silicon semiconductor device, which is an important factor in the material's performance. NBS and the Oak Ridge National Laboratory are cooperating in this project which, if successful, could mark a new era in the use of reactor-produced materials in energy fields.

Codes for Country Names Available

NBS has published a list of standard codes for country names. Both two and three letter codes are provided for use by industry, professional, trade, and government organizations that need to code countries in their information systems. The names of the countries are the official names designated by the U.S. Board of Geographic Names and the United Nations. Copies of the standard codes may be obtained upon request from the NBS Office of Technical Publications, Wash., D.C. 20234. Refer to NBS Letter Circular 1067.

New Computer SRM Issued

A Secondary Standard Magnetic Tape Cartridge has been developed by NBS as a Standard Reference Material (SRM). This unrecorded magnetic tape cartridge is for use in the signal amplitude calibration of digital tape cartridge recording and reproducing systems. The dimensions of the cartridge conform to those specified by the European Computer Manufacturers Association and the proposed American National Standards Institute Standard. SRM 3216 is available for $165.00 through the Office of Standard Reference Materials, NBS, Washington, D.C. 20234.

Samples Processed Automatically

A new, automated sample processing system has been designed and put into operation at NBS for multielemental analysis of materials by neutron activation. The system consists of an automatic sample processing mechanism for gamma-ray counting of both solid and liquid samples. Data reduction of the resulting complex gamma spectra is performed by a new computer code. The computer code locates, identifies, and quantifies individual components of the spectrum and calculates final concentration values for desired elemental components. The system has potential application in areas of science and industry where there is a need for rapid, accurate, and low-cost analysis of large numbers of similar samples.

Energy Storage Data Being Compiled

NBS is coordinating a program to compile and evaluate data on the physical properties of materials used in energy storage systems. Under contract with the Lawrence Livermore Laboratory (LLL) the NBS Office of Standard Reference Data (OSRD) will arrange for the work to be carried out through its system of data centers. This effort is part of a program, supported by the Energy Storage Division of the Energy Research and Development Administration (ERDA), to establish a computerized data bank which can be accessed by ERDA management and contractors.

A pilot study is now underway on selected properties of molten salts which have potential use in storage batteries.

Reference Data Issued

The first issue of Volume 5 of the *Journal of Physical and Chemical Reference Data* has been distributed to over 1200 subscribers. The Journal is the primary dissemination channel for the National Standard Reference Data System and is published for NBS by the American Chemical Society and the American Institute of Physics.

The new issue contains the following items: "Scaled Equation of State Parameters for Gases in the Critical Region," "Microwave Spectra of Molecules of Astrophysical Interest. IX. Acetaldehyde," "Microwave Spectra of Molecules of Astrophysical Interest. X. Isocyanic Acid," "Diffusion in Copper and Copper Alloys, Part IV. Diffusion in Systems Involving Elements of Group VIII." Copies of individual articles and subscriptions to the *Journal* may be ordered from the American Chemical Society, Room 604, 1155 – 16th Street, Washington, DC 20036. □

Test Method Determines Effect of Thermal Transients on Pressure Transducer Response

THE National Bureau of Standards has developed a test method to serve as an initial screening test to identify pressure transducers that tend to give erroneous readings when subjected to thermal radiant-energy transients.

The test method was developed by NBS' Electronic Technology Division in response to requests from the Naval Air Systems Command and the Transducer Committee of the Telemetry Group, Range Commanders Council.

The test method consists of monitoring pressure transducer output as the transducer is exposed to a transient thermal radiant-energy stimulus resulting from the ignition of a photographic flashbulb or from the discharge of an electronic flash. The method, which is described in NBS Technical Note 905 recently published, also provides for monitoring energy and duration of the transient stimulus.

The test transducer is mounted in a fixture at one end of an optical bench so that the transducer diaphragm faces toward the center of the bench. At the other end of the bench is an energy meter with its sensor also facing toward the center of the bench. The flash source is midway between the transducer diaphragm and energy meter sensor. Transducer, flash source and energy meter are all at the same distance above the bench.

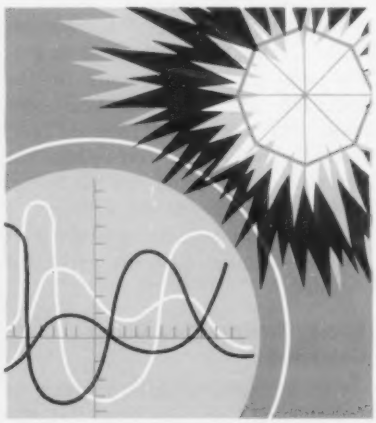
NBS also incorporated a photodiode mounted at right angles to the bench and aimed at the flash source. The photodiode was used to provide a check on the operation of the energy meter and provide information about the waveshape of the stimulus.

During a test, the pressure transducer is mounted in the fixture and provided with the manufacturer's specified excitation, if any. Monitored are: the transducer output as displayed on an oscilloscope; the reading of the energy meter; and the photodiode output, also displayed on an oscilloscope.

Commercial No. 22 photographic flashbulbs and an electronic xenon flash operated at 150 joules proved to be the most satisfactory flash sources. With the No. 22 bulb, the test method provides knowledge of the transducer zero shift as a function of measured energy level to within an estimated ±14 percent of the true value.

Twenty-five selected transducers were evaluated by the method using No. 22 flashbulbs. These represented seven models of strain-gage types and three models of piezoelectric-crystal types. Zero shifts measured ranged from 0.4 percent to about 400 percent of the full-scale readings.

Semiconductor strain gage transducers exhibited larger zero shifts than the other types of transducers tested. Within the semiconductor transducers, the largest zero shift occurred in transducers with strain gages diffused into a silicon diaphragm. Next came transducers with semiconductor strain gages bonded to a metal diaphragm. Lesser zero shifts were measured for transducers with semiconductor strain gages mounted on an auxiliary beam connected to the diaphragm by means of a push rod.



It was recommended that pressure transducers being considered for use in environments in which thermal transients are likely to exist be screened by this test method to detect, prior to use, those vulnerable to such transients. It was also recommended that the present method be extended to provide thermal radiant-energy transients with considerably greater energy content. This would contribute to the evaluation of the effectiveness of techniques for protecting a transducer from thermal transients, as well as provide a better simulation of the transients encountered in some applications.

Copies of Technical Note 905, A Test Method for Determining the Effect of Thermal Transients on Pressure-Transducer Response, may be ordered prepaid for $1.10 by SD Catalog No. C13.46:905 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Foreign remittances must be in U.S. exchange and include an additional 25 percent of the publication price to cover mailing costs. Order microfiche copies prepaid by NBS designation from the National Technical Information Center, Springfield, Va., 22151; the price is $2.25 (domestic) or $2.95 (foreign) a copy. □

Most Fire Deaths Occur at Home

DESPITE the attention given to spectacular fires in high rise buildings, nightclubs, or nursing homes, most fire deaths in the U.S. occur at home. The majority of these deaths result from carelessly left smoking materials—such as cigarettes, pipes, and cigars—igniting nearby home furnishings.

This information was reported in a recent National Bureau of Standards —National Fire Protection Association (NFPA) survey. By combining data from four major sources of fire information, Frederic B. Clarke, Center for Fire Research NBS, and John Ottoson, Fire Records Department NFPA, identified the careless smoking syndrome as one of fourteen different scenarios which together account for 66 percent of U.S. fire deaths.

In their article, "Fire Death Scenarios and Fire Safety Planning," NFPA *FIRE JOURNAL*, May 1976, Clarke and Ottoson report that "the most common fire death scenario, by far, is the residential furnishings fire caused by smoking materials, which alone accounts for 27 percent of fire deaths."

The second most typical fire death scenario is also set in the home where furnishings are ignited by an open flame. Transportation fires, apparel fires, and residential fires caused by heating and cooking equipment are on equal footing as the third most typical fire death scenario.

With the exception of transportation and apparel fires, all scenarios that involve 2 percent or more of the fire deaths occur in the home, Clarke and Ottoson report. "Thus, fatalities occuring in large office buildings, for example, or in nursing homes, are a very small piece of the whole fire death picture despite the public attention they attract," the report notes.

If the nation's goal of reducing fire losses by 50 percent over the next generation is to be accomplished, then particular attention must be paid to the residential fire problem and the role of furnishings in these fires, the authors state.

"Those features of a residence normally controlled by building codes, such as structural components and interior finish, are seldom the items first ignited in fatal fires. This distinction belongs far more often (36 percent vs. 6 percent) to furnishings.

"In other words, the building contents, not the building itself, are the most likely starting point for a fatal fire," the authors conclude.

They suggest improving the ignition-resistance of furnishing materials and installation of home smoke detectors as means of combating this problem.

By combining features of several data systems, the authors were able to pinpoint circumstances of fire deaths which were unavailable from any single source. The mainstay of the study was the Fire Incident Data Organization (FIDO) file maintained by NFPA. The FIDO file was checked against, and supplemented by, three other data sources. These were: the National Fire Data System (NFDS) of the Commerce Department's National Fire Prevention and Control Administration; the Accidental Deaths Caused by Fire and Flames, compiled annually by the Center for Health Statistics of the Department of Health, Education, and Welfare; and the Flammable Fabrics Accident Case and Testing System (FFACTS), maintained by the Consumer Product Safety Commission.

Howard D. Tipton, Administrator of the National Fire Prevention and Control Administration, praised the Clarke-Ottoson study. "This is the first time there has been an attempt to quantify fire deaths in this detail," he said, adding, "This is the sort of information we need to mount a truly effective attack on the fire problem."

Tipton said the National Fire Data Center, now in the early stages of development, will provide even more detailed information in the future so that prevention efforts can be focused more sharply. □

SRM Aids in Measuring Industrial Mercury Exposure

MORE accurate monitoring of a worker's occupational exposure to mercury will be possible as a result of a new Standard Reference Material (SRM) developed by the National Bureau of Standards. The SRM will help public health officials

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Mercury *continued*

protect some 150,000 workers who are employed in industries where mercury exposure is a daily and potentially hazardous occurrence.

SRM 2762, Freeze-Dried Urine Certified for Mercury, consists of two freeze-dried samples of human urine containing low and elevated levels of mercury when reconstituted with pure water. It is one of several SRM's for Industrial Hygiene Analysis developed in a program jointly sponsored by the National Institute of Occupational Safety and Health and NBS. The purpose of the program is to develop reference materials related to industrial hygiene analysis and for monitoring the workplace atmosphere.

Industries are not required to monitor concentrations of mercury in urine, but they are required to monitor atmospheric concentrations of mercury in the workplace. However, the main route by which mercury is eliminated from the body once it has been inhaled is through the urine.

Moreover, there is a direct correlation between mercury concentrations in the workplace and concentrations of mercury in urine, and thus many industries take monthly urine samples from workers exposed to mercury. The new SRM, therefore, will provide industrial hygiene chemists with accurate means for calibrating equipment and methods that are used to determine if workers have been unduly exposed to high atmospheric concentrations of mercury in the workplace.

Mercury is of special concern to public health officials because it is so widely used. It is a prime component in the electrical apparatus industry for the manufacture of dry cell batteries, switches, and other electrical components. One of its most important uses is in the production of two industrially important chemicals, chlorine and caustic soda.

Last year in these two industries alone, more than 1,000 metric tons were used. Because of its versatile and unique properties, mercury and its compounds are also used in pharmacology, the paint industry, agriculture, and other industries for a total U.S. consumption of 1,700 metric tons.

Today, exposure to mercury usually occurs through inhalation of its vapors. Federal health standards designed to protect workers from mercury require monitoring of atmospheric mercury concentrations. To assist in this task, NBS recently developed a mercury monitor that is worn by a worker in his breathing zone. This monitor, along with the new SRM for mercury in urine, will help officials identify hazardous concentrations of mercury in the workplace and take corrective actions.

SRM 2672 is issued in sets of two bottles containing the freeze-dried material for *in situ* reconstitution at a cost of $80.

Other SRM's in the Industrial Hygiene Analysis series are:

—SRM 2671 Freeze-Dried Urine Certified for Fluoride

—SRM 2675 Beryllium on Filter Media

—SRM 2676 Metals on Filter Media (lead, cadmium, zinc, and manganese)

A fifth SRM for Industrial Hygiene Analysis, Quartz on Filter Media (SRM 2679), is expected soon.

For information on ordering SRM's, write to: Office of Standard Reference Materials, Room B311, Chemistry Bldg., National Bureau of Standards, Washington, D.C. 20234. □

NBS to Offer Additional Service for High-Capacity Mechanical Testing

THE National Bureau of Standards is initiating a national referral service for academic, engineering, and industrial organizations requiring high-capacity mechanical testing.

This "Mechanical and Structural Testing and Referral Service," (MASTARS), is presently compiling a comprehensive MASTAR FILE of all U.S. mechanical testing facilities with capacities exceeding 4.4 meganewtons (Mn) (1 million lbf), which are available for contract work.

The new service parallels and strengthens the testing and research program which NBS now offers with its 53 Mn (12 million lbf) universal testing machine. This unique facility, considered to be a national resource, is available, at cost, to the entire technological communiy for work that cannot be done by the private sector. An agency of the U.S. Department of Commerce, NBS provides these services in support of the Department's commitment to use the government's technology resources to help fulfill national needs.

Prior to inauguration of MASTARS, requests for research and testing services were refused by NBS when required capabilities were available in the private sector. Now, to aid the requestor and to stimulate private research and testing, the Bureau will direct inquiries, on an impartial basis, to private laboratories with those capabilities.

To be included in the MASTAR FILE or to obtain NBS research and testing services, interested parties should write MASTARS, EM 219, National Bureau of Standards, Washington, D.C. 20234 or call program manager A. F. Kirstein, telephone (301) 921–2621. □

Implants *continued*

the desirable properties of materials and correlate them with actual performance."

Although the NBS research is a long way from reaching this goal, significant information has been gained on one part of this problem, protein adsorption on implant surfaces. This is the first event that occurs when a synthetic implant material is inserted in the cardiovascular system—blood proteins become bound chemically or physically to the surface of the material. In the process, the proteins may change their shape or conformation, an event that may alter their biological activity and possibly be related to the initiation of the clotting process.

"Clots on the surface of an implant, especially a heart valve, are dangerous," Smith stresses, "since they can impair the function of the valve, or the clots can break loose and travel to other parts of the body where they can block the circulation."

NBS chemists Dr. Robert Stromberg, Dr. Bruce Morrissey, Dr. Warren H. Grant, and Dr. Ronald E. Dehl have approached the problem by looking at changes in the shape or conformation of proteins that might occur as a function of concentration, surface charge, pH, and ionic strength when they are adsorbed onto synthetic surfaces.

Using infrared spectroscopy and ellipsometry, their studies so far show that the amounts of three important blood proteins—prothrombin fibrinogen, and serum albumin—adsorbed from physiological concentrations remained approximately constant for a number of materials. However, the thickness of the protein film (a measure of the molecular conformation of the protein on the surface) changes as the surface energy, estimated by contact angle measurements, of the material changes. The higher the surface energy of the material, the thinner the film. "So far, most successful implant materials fall in the same general range of surface energies," Smith observes.

Other properties of the proteins have been studied as well, but as Morrissey is quick to point out, "Although we've learned a lot about characterizing the interaction of plasma proteins with various materials, we're just at the beginning of understanding a basis for predicting the nature of the interaction of blood with artificial devices."

In fact, he adds, "It seems that the most relevant questions are also the most basic and toughest to answer when it comes to predicting what properties of materials will make good implants." Though his statement refers to cardiovascular implants, the same holds true for nearly all the other implant areas.

When it comes to the human body and the myriad materials that could possibly be used, there are no easy answers. But scientists, surgeons, and other specialists are searching deeply into the problems presented by both in the hope of making the tricky replacement of worn out body parts safer and more reliable. □

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of the National Bureau of Standards

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Metrology: Physical Measurements

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